PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Power-Operated Manipulator

We, A. C. WILSON & PARTNERS LIMITED, a British Company, of Design House, The Mall, Ealing, London, W.5, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement: —

The present invention relates to manipulators intended for the remote manipulation of objects inside a building, cave, laboratory or cell within which radioactive conditions make it impossible to perform direct manipulation.

Manually operated manipulators are already known which permit objects to be manipulated from outside such a compartment, but the loads that can be moved and the forces which can be exerted thereby are strictly limited by the strength of the human body.

It is an object of the present invention to provide a power-actuated manipulator which is capable of handling much larger loads and of exerting much larger forces than has been possible with the known manually operated devices. A power actuated manipulator in accordance with the present invention may be constructed, for example, to lift loads of the order of one ton and to exert vertical and horizontal thrusts of the order of half a ton.

According to the present invention a manipulator comprises a carriage movable along a longitudinal track, the carriage carrying a transverse track, a cross trolley movable along the transverse track carried by the carriage, a vertical telescopic arm rotatably supported in the cross trolley, an implement carried by the arm, at least one telescopic implement drive shaft located within the telescopic arm and expanding and contracting with the telescopic arm and motor means for the implement drive shaft secured to turn with the telescopic arm. There are, in fact, preferably at least two implement power take-off drive shafts located within the telescopic arm and driven by separate motors mounted on the rotatable head.

It will be appreciated that all the motions of the manipulator must be provided with separate motor means and each of such motor means must be controllable from outside the compartment within which the manipulator is located. Individual hydraulic motors are preferred for providing the drive to each of the moving elements of the manipulator, since hydraulic motors of the gear type are fully reversible and are capable of being compactly constructed and of transmitting torque of a magnitude sufficient to produce the ultimate forces required of the manipulator. The most important advantages obtained from the use of hydraulic motors are: —

(a) The incorporation of feed-back characteristics into the control apparatus for the motors, so that the operator can feel the force which is being exerted on the object being manipulated, in the like manner to which "feel" is built into the control system of power-operated aircraft controls.

(b) Very precise control over "inching" movement.

(c) High torque at low and zero speed.

(d) Very compact drive arrangements.

(e) Freedom from radiation damage at high level gamma and thermal neutron fluxes.

Although hydraulic motors are preferred, it will be appreciated that electric or pneumatic motors might be substituted therefor.

Although the use of hydraulic motors do provide definite advantages in ease of control of the various motions of the manipulator, special precautions have to be taken to prevent loss of hydraulic oil within the compartment, since this oil will in turn become highly radio-active and present very considerable

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problems for cleaning up the floor of the compartment and for disposal.

In the construction of the apparatus hereinafter described in greater detail special precautions have been taken to prevent loss of oil from the hydraulic system. At the same time, the exposed parts of the drive system have been constructed of specially chosen materials so that they can run dry for prolonged periods.

One manipulator constructed in accordance with the present invention is hereinafter described with reference to the accompanying drawings wherein:—

Figure 1 is a partly diagrammatic perspective illustrating the motions of the manipulator,

Figure 2 is a front view of the manipulator,

Figure 3 is a plan view of the manipulator,

Figure 4 is an underneath view of the cross trolley without the rotatable head,

Figure 5 is a cross section of the cross trolley with the power take off drives omitted,

Figures 6 and 6A are a section on a larger scale of the telescopic tube structure, and

Figure 7 is a section of the hydraulic slip ring assembly.

The manipulator is intended for mounting near the ceiling of an enclosed compartment and is supported by channel section track members built into the side walls of the compartment.

The carriage 2 of the manipulator has a rectangular frame built up of girders and this is provided with main flanged rollers 3 which rest on the lower flanges of the track members 1 and upper reactive rollers 4, which engage under the upper flanges to prevent the carriage 2 from tilting laterally or longitudinally when a horizontal tractive effort or force is applied by the telescopic tube assembly 5.

The propulsion of the carriage 2 is effected by means of an underslung cross shaft 6 which carries a pair of pinions 7, which mesh with rack members 8 (Figure 2) carried on the webs of the track members 1. The carriage 2 is provided with a hydraulic motor and reduction drive unit 9 to drive the cross shaft 6. The cross shaft 6 and motor 9 are arranged towards one side of the carriage 2, so as to leave the central area clear for a cross trolley 10, which is likewise supported by two channel section track members 11 which form part of the frame of the carriage 2. The cross trolley 10 is supported and driven in the same way as the carriage 2, being supported by main rollers 12 and upper rollers 14 and driven by pinions 15 engaging racks 16. A solenoid actuated clutch is preferably provided in the drive to the pinions 15, so as to permit the drive to be disconnected in the event of failure of the hydraulic motor of the cross trolley, which can then be moved manually lengthwise of its track.

The pinions 15 are mounted on a shaft 17, which is driven by a hydraulic motor 18 carrying a pinion 19 engaging with a pinion 20 splined on the shaft 17. The pinion 20 is disengageable from the pinion 19 by means of a yoke 21 actuated by a solenoid 22 (Figure 4).

A rotatable head 25 is arranged in a central aperture 26*a* of the cross trolley 10. The rotatable head (Figure 5) includes a base casting, which provides a circular table 26 and a downwardly projecting tubular portion 27, which lies within a like tubular portion 28 at the centre of the cross trolley frame. The loads to be transferred from the rotatable head 25 to the trolley 10 are taken by means of upper and lower taper-roller combined journal and thrust bearings 29 and 30 arranged between the tubular portions of the trolley and the rotatable head base casting, the thrust bearings being opposed to transmit both upward and downward thrusts, and also normal or journal loads.

The drive for the rotatable head 25 comprises a hydraulic motor 32 horizontally mounted on the underside of the body of the cross trolley 10. This motor drives a vertical shaft 33 through a bevel drive and the top end of the shaft projects through the trolley body and carries a pinion 34, which engages with a ring gear 35 secured on the underside of the table portion 26 of the base casting.

The rotatable head supports three hydraulic motors one of which is shown at 36 in Figure 5. These motors are bolted on top of the table 26 so that they turn with it. The hydraulic circuit of these motors is through a hydraulic slip ring system that will be described later in detail.

The tubular portion 27 of the base casting acts as the support for telescopic tube structure 5. This structure comprises three coaxial tubes 38, 39 and 40, each about 5 ft. long, the outer tube 38 being secured inside the tubular portion 27. Since the purpose of rotating the head 25 is to impart a like movement to the object to be manipulated, it follows that the foot end of the telescopic arm tube structure 5 must be made to turn with the rotatable head and therefore the tubes 38, 39 and 40 must be prevented from rotating with respect to each other.

Phosphor bronze bushes 41 and 41^1 are secured in the foot end of the outer and middle tubes 38 and 39 and a key 42 and 42^1 is secured to each of the two tubes in longitudinal grooves in these bushes, the keys 42 and 42^1 engaging in corresponding keyways 43 and 43^1 cut in the outer surface of the middle and inner tubes 39 and 40. This arrangement ensures that when the telescopic tube structure 5 is extended, it may exert torsional and horizontal forces without undue lash or deflection. The telescoping drive

mechanism, by means of which the arm can be employed to exert both lift and downward thrust, as well as for positioning the power-driven implements supported by the arm, is driven by the motor 36 (Fig. 5). The drive mechanism comprises a two-part steel acme screw running in lead-bronze nuts. The inner primary part 44 of the acme screw is supported at its top end in ball thrust races 45 and 45[1] in the centre of the table 26. It carries a bevel pinion 46 to mesh with reduction gearing driven by the motor 36. The primary screw 44 is threaded into a nut insert 47 secured in the top end of the hollow secondary screw 48, which is in turn threaded into a nut 49, which in fact is formed integral with a carrier casting secured in the top end of the inner tube 40. The carrier plate 50 is secured in the top end of the intermediate tube 39 and the primary screw 44 slides in flanged bushings 51 and 52 mounted in this plate, the lower bushing 52 bearing against the top end of the secondary screw 48, so that the intermediate tube 39 is supported by it.

When the primary screw 44 is rotated, the friction between the screws and their respective nuts will determine whether the secondary screw 48 turns or not and this will determine whether the intermediate tube 39 or the inner tube 40 moves first. There is, of course, a stop at both ends to ensure that when the secondary screw 48 is fully wound out or wound in, it commences to turn with the primary screw 44.

The inner tube 40 has a bottom plate 54 welded into its bottom end and two power take-off implement supporting spindles 55 are supported eccentrically in flanged bushings 56 in this plate. The protruding bottom ends of these spindles 55 are suitably formed to permit appropriate implements to be secured thereto. The drive for these spindles is derived from two hydraulic motors (not shown) mounted on the table 26 and is transmitted through telescopic drive shafts which are drawn in and out with the telescopic tube assembly itself.

Each telescopic drive shaft comprises a top spindle 57 journalled in the table 26 and driven through a bevel pinion 58. The top spindle 57 is secured to a square section shaft 60, which in turn is in sliding engagement in a square section intermediate drive tube 61. The intermediate drive tube 61 has a collar 62 secured to its top end and this collar is rotatably supported in bearings 63 mounted in the carrier plate 50 secured in the top of the intermediate tube 39. The square section intermediate drive tube 61 is in turn engaged in a square section final drive tube 64, likewise provided with a collar 65 mounted in bearings 66 in the carrier casting 49 in the top end of the inner tube 40 of the telescopic tube assembly. The final drive tube 64 is secured to one of the implement spindles 55.

The pressure supply of hydraulic fluid to drive the hydraulic motors is supplied by one or more pumps located externally of the manipulator compartment through valves which are manually controlled by an operator from one or more fixed positions externally of the compartment, from which he can watch operations. Each motor is fully reversible and, in consequence, is provided with two separate hydraulic lines going back to its control valve, each line serving alternatively as a pressure inlet line and as a return line.

Since all the motors are movable in relation to the hydraulic pumps and the controls, the supply of fluid to the motors presents certain problems. The carriage 2 carries a manifold or distribution board 70, through which all the hydraulic lines pass and in which they are secured. In the construction of the manipulator as described above, there are six hydraulic motors and this entails twelve hydraulic supply lines passing through the distribution board and in addition there is a drain or bleed line, the purpose of which will be explained below.

The distribution board 70, which is rigidly secured to the carriage 2, is connected with the controls of the hydraulic system by flexible pipes 71, which lead from fixed points in the roof of the compartment to the distribution board. These flexible pipes are arranged to be drawn out or to retract into the roof in known manner, according to whether the carriage is moved away from or towards the stationary end of the pipes.

From the distibution board, hydraulic fluid is supplied through metal pipes to the carriage drive motor 9, passing intermediately through decelerator valves (not shown). Hydraulic fluid, after similarly passing through decelerator valves, is also fed directly from the distribution board through flexible pipes 72 to the cross trolley drive motors 18 and the motor 32 for rotating the head. These two motors move linearly with regard to the distribution board 70 and present no particular problem.

On the other hand, the three motors supported on the table 26 of the rotatable head can in fact be turned continuously in either direction with regard to the distribution board 70 and it is, in consequence, necessary to provide a hydraulic slip ring assembly 74 between the distribution board 70 and these three motors. The slip ring assembly 74 is supported on a platform 75 above the table 26 of the rotatable head.

The slip ring assembly (Figure 7) has a central post member 80 which is secured to the platform 75 so that it rotates with the head: It has internal passages 81 through which the fluid passes to and from the motors and an external ring structure 82, which is connected by flexible pipes 83 to the dis-

tribution board 70. The external ring structure 82 is connected by telescopic torque reaction members 84, which are secured by a pivot 85 to the carriage 2 and hold the ring structure 82 from rotating freely.

As has already been pointed out, it is desirable to ensure that, for a manipulator working in highly radio-active surroundings, the escape of oil should be reduced to a minimum. To assist in this purpose, the spindle of each hydraulic motor is provided with inner and outer spaced oil seals and a bleed line is connected to the space between the two oil seals to lead away any oil that leaks past the inner oil seal. All these bleed lines are led into a common bleed line at the distribution board 70.

This principle of bleeding away any leakage from the space between inner and outer oil seals is also employed in the construction of the hydraulic slip ring assembly, which forms a special feature of the present construction.

The hydraulic slip ring comprises the central post 80, which is drilled longitudinally to form seven galleries to provide six supply line galleries 81 for the three motors supported on the table 26 and a bleed line gallery 81^1, common to the three motors, for the oil leakage past the primary seals in the slip ring assembly itself.

The ends of the longitudinal drillings are all plugged and near the bottom end of each gallery 81, 81^1 a pipe union rocket 87 is tapped in through the side of the post. These sockets provide for the seven connections (not shown) leading to the three motors on the table 26 and are arranged in a ring around the bottom end of the post 80.

Above this ring of sockets the post 80 is provided with an annular shoulder 88 on which the stationary ring structure 82 is supported, the ring structure being held down against this shoulder by a cover plate 89 secured to the top end of the post 80.

The ring structure has seven pipe connection rings 90, each of which is provided with a pipe union 91 threaded into a radial drilling, the unions 91 being connected to the flexible pipes 83. The seven galleries 81 and 81^1 in the post are cross drilled to provide a port 92 at a height corresponding to that of the appropriate connection ring. The seven connection rings 90 are held together by bolts 93 with spacer rings 94 arranged between each of them and with gland rings 95 and 95^1 at each end of the assembly. The spacer rings 94 are a close fit on the post 80, whilst the internal diameter of the connection rings 90 is much larger, so as to leave an annular passage between the ring and the post.

Oil seals 96 are arranged at each side of each annular passage to top the passage of oil longitudinally from one annular passage to the next and these oil seals are supported by the spacer rings (and the gland rings at the two ends). The oil seal rings 96 are held apart against the spacer rings 94 by distance rings 97 made of perforated metal, the edges of which are received in the grooves in the neoprene oil seal rings. Each oil seal and its backing formed by the adjacent spacer rings (or gland rings) defines an annular passage around the post 80, so that fluid entering through the connection ring 90 can enter the appropriate gallery 81 in the post, via a port 92.

The oil seals 96 are the primary oil seals and secondary oil seals are provided spaced therefrom, fluid from the space between the primary and secondary oil seals being bled away as in the case of the motors, to a main bleed line.

There is already in the post one gallery 81^1 through which fluid is bled back from the motors and this is utilised to bleed away the fluid which passes the primary seals 96.

The secondary seals are formed by means of "O" rings 98 located in grooves in the top face of each connection ring 90, each spacer ring 94 and the bottom gland ring 95, to prevent fluid, which has leaked past the primary seals from seeping radially out between adjacent rings.

Each spacer ring 94 has an annular groove 99 in its inner periphery and is formed with longitudinal drillings 100 at intervals to provide passages which connect the area behind the neoprene oil seal rings 96 of the primary oil seals with this groove. Each groove 99 is itself in register with a drilling 101 in the post leading into the bleed line gallery 81^1, so that fluid leaking past the primary oil seals 96 is led into the bleed line gallery 81^1.

The top gland ring 99 is formed to provide an annular passage around the post from which fluid is led back into the bleed line gallery. This annular passage is provided with a secondary seal, which is in effect half of one of the primary oil seals, a neoprene ring 102 at the top of the passage being supported by a distance ring 103, onto which it is pressed down by a thrust washer 104, bearing against the cover plate 89 at the top end of the post.

The bottom gland ring 95^1 is of similar construction to the top gland ring and its neoprene sealing ring 105 is supported on a thrust washer 106 bearing against the supporting shoulder 88 on the post. The fluid leaking downward past the bottom primary seal 96 is led from the space in the bottom gland ring into a separate gallery (not shown) in the post, and this small quantity of hydraulic oil is led away for lubricating purposes.

The bottom gland ring 95 has torque shaft brackets 107 (Figure 3) secured to it to receive the torque reaction members 84 which are connected to the carriage 2 to hold the slip ring structure against rotation.

The operations which can be performed

by the manipulator may be most readily understood from a consideration of Figure 1, in which a power-operated clamp 110 is shown attached to the foot end of the telescopic tube assembly. The clamp 110 is only one of many different implements or tools which may be interchangeably attached to the tube assembly 5.

It will be appreciated from the foregoing description of the construction of the apparatus that there are six hydraulic motors, each of which is separately controlled and each of which produces a separate motion in the system.

Three of the hydraulic motors produce linear motions, by means of which the clamp 110 can be moved to any spatial position within the limitations of the system. These motions of the clamp are produced by the longitudinal movement of the carriage 2 and lateral movement of the cross trolley 10 in the horizontal plane and the telescoping movement in the vertical plane of the tubes of the tube assembly 5.

The jaws 111 of the clamp 110 may be presented at any desired angle to an object to be grasped by rotation of the tube assembly 5, which is effected by rotation of the head 25.

The additional two rotary motions are applied through the two implement spindles 55, which may be used to produce motion in the implements supported by the tube assembly 5. In the clamp 110, for instance, the rotation of the spindles 55 produces movement of the jaws 111 to effect the desired clamping action.

In addition to its obvious ability to lift loads and place them at different positions, the tube assembly may also be employed to produce horizontal thrusts in any desired direction and likewise a downward thrust. The rotational torque that may be applied through the tube assembly may be applied to such tasks as the rotation of valve controls and the operation of box spanners for tightening or loosening nuts and bolts.

WHAT WE CLAIM IS:—

1. A manipulator comprising a carriage movable along a longitudinal track, the carriage carrying a transverse track, a cross trolley movable along the transverse track carried by the carriage, a vertical telescopic arm rotatably supported in the cross trolley, an implement carried by the arm at least one telescopic implement drive shaft located within the telescopic arm and expanding and contracting with the telescopic arm and motor means for the implement drive shaft supported to turn with the telescopic arm.

2. A manipulator according to Claim 1, wherein the telescopic arm comprises a plurality of co-axially arranged tubular members, longitudinally movable but non-rotatable relative to each other, supported by a rotatable head carrying separate motor means for each implement drive shaft.

3. A manipulator according to Claim 2, wherein the relative movement of the tubular members is provided by a screw and nut assembly driven by motor means supported by the rotatable head.

4. A manipulator according to any preceding claim, wherein each motor means is a hydraulic motor, connected through a valve under the control of an operator with a remotely located hydraulic fluid pressure supply.

5. A manipulator according to Claim 2, wherein a plurality of hydraulic motors are supported by the rotatable head and are connected through a hydraulic slip ring assembly by flexible hoses to fixed connection points on the carriage.

6. A manipulator according to Claim 5 wherein the hydraulic slip ring assembly comprises a central member secured to the rotatable head and an external ring structure held against free rotation, said central member having a plurality of galleries formed therein, each of which has a port axially spaced from the ports of the other galleries and each port coinciding with an annular space between the external ring structure and the central member, each annular space being provided with a passage through the ring structure.

7. A manipulator according to Claim 6 in which the external ring structure comprises a plurality of connection rings of greater internal diameter than the central member, and spacer rings fitting closely to the central member between adjacent connection rings, said connection rings and spacer rings being clamped together so that an annular space is defined between each connection ring and the central member.

8. A manipulator according to Claim 7 wherein primary and secondary oil seals are provided against leakage of hydraulic fluid between the connection rings and the spacer rings, the spaces between said primary and secondary oil seals being vented into a bleed gallery in the central member.

9. A manipulator constructed and adapted to operate substantially as herein described with reference to the accompanying drawings.

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Chartered Patent Agents,
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PROVISIONAL SPECIFICATION

Power-Operated Manipulator

We, A. C. WILSON & PARTNERS LIMITED, a British Company, of Design House, The Mall, Ealing, London, W.5, do hereby declare this invention to be described in the following statement:—

The present invention relates to manipulators intended for the remote manipulation of objects inside a building, cave, laboratory or cell within which radioactive conditions make it impossible to perform direct manipulation.

Manually operated manipulators are already known which permit objects to be manipulated from outside such a compartment, but the loads that can be moved and the forces which can be exerted thereby are strictly limited by the strength of the human body.

It is an object of the present invention to provide a power-actuated manipulator which is capable of handling much larger loads and of exerting much larger forces than has been possible with the known manually operated devices. A power actuated manipulator in accordance with the present invention may be constructed, for example, to lift loads of the order of one ton and to exert vertical and horizontal thrusts of the order of half a ton.

According to the present invention a manipulator comprises a carriage movable along a longitudinal track, the carriage carrying a transverse track, a cross trolley movable along the transverse track carried by the carriage, a rotatable head supported by the cross trolley, a vertical telescopic arm supported by the rotatable head and rotatable therewith, at least one telescopic implement drive shaft located within the telescopic arm and expanding and contracting with the telescopic arm and motor means for the drive shaft secured to the rotatable head. There are, in fact, preferably at least two implement power take-off drive shafts located within the telescopic arm and driven by separate motors mounted on the rotatable head.

It will be appreciated that all the motions of the manipulator must be provided with separate motor means and each of such motor means must be controllable from outside the compartment within which the manipulator is located. Individual hydraulic motors are preferred for providing the drive to each of the moving elements of the manipulator, since hydraulic motors of the gear type are fully reversible and are capable both of being compactly constructed and of transmitting torque of a magnitude sufficient to produce the ultimate forces required of the manipulator. The most important advantages obtained from the use of hydraulic motors are:—

(a) The incorporation of feed-back characteristics into the control apparatus for the motors, so that the operator can feel the force which is being exerted on the subject being manipulated, in the like manner to which "feel" is built into the control system of power-operated aircraft controls.

(b) Very precise control over "inching" movement.

(c) High torque at low and zero speed.

(d) Very compact drive arrangements.

(e) Freedom from radiation damage at high level gamma and thermal neutron fluxes.

Although hydraulic motors are preferred, it will be appreciated that electric or pneumatic motors might be substituted therefor.

Although the use of hydraulic motors do provide definite advantages in ease of control of the various motions of the manipulator, special precautions have to be taken to prevent loss of hydraulic oil within the compartment, since this oil will in turn become highly radioactive and present very considerable problems for cleaning up the floor of the compartment and for disposal.

In the construction of the apparatus hereinafter described in greater detail special precautions have been taken to prevent loss of oil from the hydraulic system. At the same time, the exposed parts of the drive system have been constructed of specially chosen materials so that they can run dry for prolonged periods.

One manipulator constructed in accordance with the principle of the present invention is intended for mounting near the ceiling of an enclosed compartment and is supported by track members built into the side walls of the compartment. The track members are channel sections.

The carriage of the manipulator has a rectangular frame built up of girders and this is provided with main flanged rollers which rest on the lower flanges of the track members and upper reactive rollers, which engage under the upper flanges to prevent the carriage from tilting laterally or longitudinally when a horizontal tractive effort or force is applied by the telescopic tube assembly.

The propulsion of the carriage is effected by means of an underslung cross shaft which carries a pair of pinions, which mesh with rack members carried on the webs of the track members. The carriage is provided with a hydraulic motor which is connected to drive the cross shaft through a suitable reduction drive. The cross shaft and motor are arranged towards one end of the carriage, so as to leave the central area clear for a cross trolley. The cross trolley is likewise supported by two channel section track members which form part of the frame of the carriage. The cross trolley is supported and driven in the same way as the carriage. One pinion in the gear

train between the cross trolley motor and its drive pinion is preferably splined to its shaft and is provided with a solenoid-actuated yoke for moving it lengthwise of its shaft, so as to permit the drive to be disconnected in the event of failure of the hydraulic motor. The cross trolley can then be moved manually lengthwise of its track.

A rotatable head is arranged at the centre of the cross trolley. The rotatable head includes a base casting, which provides a circular table and a downwardly projecting tubular portion, which lies within a like tubular portion at the centre of the cross trolley frame. The loads to be transferred from the rotatable head to the trolley are taken by means of upper and lower taper-roller combined journal and thrust bearings arranged between the tubular portions of the trolley and the rotatable head base casting, the thrust bearings being opposed to transmit both upward and downward thrusts, and also normal or journal loads.

The drive for the rotatable head comprises a hydraulic motor horizontally mounted on the underside of the body of the cross trolley. This motor drives a vertical shaft through a bevel drive and the top end of the shaft projects through the trolley body and carries a pinion, which engages with a ring gear secured on the underside of the table portion of the base casting.

The rotatable head supports three hydraulic motors, which are bolted on top of the casting so that they turn with it. The hydraulic circuit of these motors is through a hydraulic slip ring system that will be described later in detail.

The base casting of the rotating head acts as the support for a telescopic arm structure. This structure comprises three co-axial tubes about 5 ft. long, the outer of which is secured inside the tubular portion of the base casting of the rotatable head. Since the purpose of rotating the head is to be able to impart a like movement to the object to be manipulated, it follows that the foot end of the telescopic arm must be made to turn with the rotatable head and therefore the tubes of the telescopic arm must be prevented from rotating with respect to each other.

Phosphor bronze bushes are secured in the foot end of the outer and middle tubes and a key is secured to each of the two tubes in longitudinal grooves in these bushes, the keys engaging in corresponding keyways cut in the outer surface of the middle and inner tubes. This arrangement ensures that when the telescopic arm is extended, it may exert torsional and horizontal forces without undue lash or deflection. The telescoping drive mechanism, by means of which the arm can be employed to exert both lift and downward thrust, as well as for positioning the power-driven implements supported by the arm, comprises a two-part steel acme screw running in lead-bronze nuts. The inner, primary part of the acme screw is supported at its top end in ball thrust races in the centre of the base plate of the rotatable head. It is rotated by means of a hydraulic motor which drives through a reduction drive to a bevel gear carried on the top end of the screw. The primary screw is threaded into a nut insert secured in the top end of the hollow secondary screw, which is in turn threaded into a nut, which in fact is formed integral with a carrier casting secured in the top end of the inner tube. A carrier plate is secured in the top end of the intermediate tube and the primary screw is held in flanged bushings in this plate, the lower bushing bearing against the top end of the secondary screw, so that the intermediate tube is supported thereby.

When the primary screw is rotated, the friction between the screws and their respective nuts will determine whether the secondary screw turns or not and this will determine whether the intermediate tube or the inner tube moves first. There is, of course, a stop at both ends to ensure that when the secondary screw is fully wound out or wound in, it commences to turn with the primary screw.

The inner tube has a bottom plate welded into its bottom end and two power take-off implement supporting spindles are supported eccentrically in flanged bushings in this plate. The protruding bottom ends of these spindles are suitably formed to permit appropriate implements to be secured thereto. The drive for these spindles is derived from two hydraulic motors on the rotatable head and is transmitted through telescopic drive shafts which are drawn in and out with the telescopic arm itself.

Each telescopic drive shaft comprises a top spindle jornalled in the rotatable head base plate and driven through a bevel drive. The top spindle is secured to a square section shaft, which is in sliding engagement in a square section intermediate drive tube. The intermediate drive tube has a collar secured to its top end and this collar is rotatably supported in bearings in the carrier plate secured in the top of the intermediate tube. The square section intermediate drive tube is in turn engaged in a square section final drive tube, likewise rotatably supported in the carrier casting in the top end of the inner tube of the telescopic arm, the final drive tube being secured to one of the implement spindles.

The hydraulic fluid, by which the hydraulic motors are turned, is supplied under pressure by one or more hydraulic pumps located externally of the compartment through valves which are manually controlled by an operator from one or more fixed positions externally of the compartment, from which he can watch

operations. Each motor is fully reversible and, in consequence, is provided with two separate hydraulic lines going back to its control valve, each line serving alternatively as a pressure inlet line and as a return line.

Since all the motors are movable in relation to the hydraulic pump and the controls, the supply of fluid to the motors presents certain problems. The carriage carries a manifold or distribution board, through which all the hydraulic lines pass and in which they are secured. In the construction of the manipulator as described above, there are six hydraulic motors and this entails twelve hydraulic supply lines passing through the distribution board and in addition there is a drain or bleed line, the purpose of which will be explained below.

The distribution board, which is rigidly secured to the carriage in the middle at one end, is connected with the controls of the hydraulic system by flexible pipes, which lead from fixed points in the roof of the compartment to the distribution board. These flexible pipes are arranged to be drawn out or to retract into the roof in known manner, according to whether the carriage is moved away from or towards the stationary end of the pipes.

From the distribution board, hydraulic fluid is supplied through metal pipes to the carriage drive motor, passing intermediately through decelerator valves. Hydraulic fluid, after similarly passing through decelerator valves is also fed directly from the distribution board through flexible pipes to the cross trolley drive motor and the motor for rotating the head. These two motors move linearly with regard to the distribution board and present no particular problem.

On the other hand, the three motors supported on the base plate of the rotatable head can in fact be turned continuously in either direction with regard to the distribution board and it is, in consequence, necessary to provide a hydraulic slip ring between the distribution board and these three motors. The slip ring is supported above the base casting of the rotatable head and has a central post member which rotates with the head and has internal passages through which the fluid passes to the motors and an external ring structure, which is connected by flexible pipes to the distribution board. The external ring structure is connected by telescopic torque reaction members to the frame of the cross trolley to prevent it rotating. The actual construction of the hydraulic slip ring will be given below in greater detail.

As has already been pointed out, it is desirable to ensure that, for a manipulator working in highly radio-active surroundings, the escape of oil should be reduced to a minimum. To assist in this purpose, the spindle of each hydraulic motor is provided with inner and outer spaced oil seals and a bleed line is connected to the space between the two oil seals to lead away any oil that leaks past the inner oil seal. All these bleed lines are led into a common bleed line at the distribution board.

This principle of bleeding away any leakage from the space between inner and outer oil seals is also employed in the construction of the hydraulic slip ring, which forms a special feature of the present construction and can be employed in other applications where it is necessary to lead in hydraulic fluid to motors or other hydraulic devices mounted on a rotatable support.

The hydraulic slip ring comprises a central post, which is supported above the table of the rotatable head by pillars and turns with the head. This post is drilled longitudinally to form seven galleries to provide six supply lines for the three motors and a bleed line, common to three motors, for the oil leaking past the primary seals in the slip ring itself.

The ends of the longitudinal drillings are all plugged and near the bottom end of each gallery, a pipe union is tapped in through the side of the post. These pipe unions provide for seven connections leading to the motors and are arranged in a ring around the bottom end of the post.

Above this ring of unions the post is provided with an annular shoulder on which the stationary ring structure is supported, the ring structure being held down against this shoulder by a cover plate secured to the top end of the post.

The ring structure has seven pipe connection rings, each of which is provided with a pipe union threaded into a radial drilling. The seven galleries in the post are cross drilled to provide a port at a height corresponding to that of the appropriate connection ring. The seven connection rings are bolted together, with spacer rings arranged between each of them and with gland rings at each end of the assembly. The spacer rings and gland rings are a close fit on the post, whilst the internal diameter of the connection rings is much larger, so as to leave an annular passage between the ring and the post.

An oil seal is arranged on either side of each annular passage to stop passage of oil longitudinally from one annular passage to the next and these oil seals are supported by the spacer rings (and the gland rings at the two ends). Each oil seal comprises a pair of "U" section neoprene rings, having annular grooves in their opposed faces. These rings are held apart against the spacer rings by a distance ring made of perforated metal, the edges of which are received in the grooves in the neoprene rings. Each oil seal and its backing formed by the adjacent spacer rings, (or gland rings) defines an annular passage around the post, so that fluid entering through the

connection ring can enter the appropriate gallery in the post.

These oil seals are the primary oil seals and secondary oil seals are provided spaced therefrom, fluid from the space between the primary and secondary oil seals being bled away, as in the case of the motors, to a main bleed line.

There is already in the post one gallery through which fluid is bled back from the motors and this is utilised to bleed away the fluid which passes the primary seals.

The secondary seals are formed by means of "O" rings located in grooves in the top face of each connection ring, each spacer ring and bottom gland ring, to prevent fluid, which has leaked past the primary seals from seeping radially out between adjacent rings.

Each spacer ring has an annular groove in its inner periphery and is longitudinally drilled at intervals to provide passages which connect the area behind the neoprene rings of the primary oil seals with this groove. The groove itself is in register with a drilling in the post leading into the bleed line gallery, so that fluid leaking past the primary oil seal is led into the bleed line gallery.

The top gland ring is formed to provide an annular passage around the post from which fluid is led back into the bleed line gallery. This annular passage is provided with a secondary seal, which is in effect half of one of the primary oil seals, a neoprene ring at the top of the passage being supported by a distance ring, onto which it is pressed down by a thrust washer, bearing against the cover plate at the top end of the post.

The bottom gland ring is of similar construction to the top gland ring and its neoprene sealing ring is supported on a thrust washer bearing against the supporting shoulder on the post. The fluid leaking downwards past the bottom primary seal is led from the space in the bottom gland ring into a separate gallery in the post, and this small quantity of hydraulic oil is led away for lubricating purposes.

The bottom gland ring has torque shaft brackets secured to it to receive the torque shafts which are connected to the cross trolley to hold the slip ring structure against rotation.

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Agents for the Applicants.

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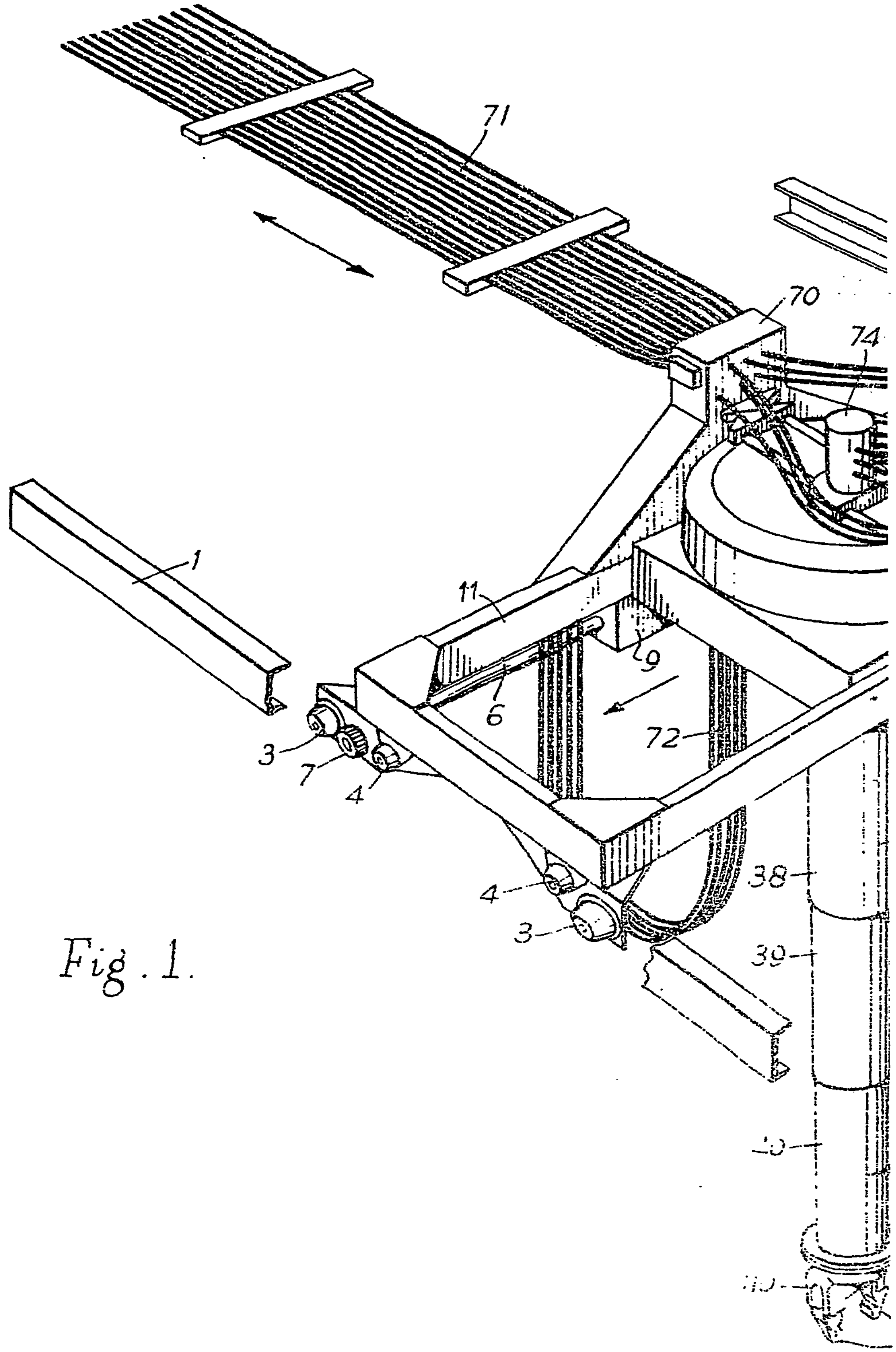

Fig. 1.

859,162 COMPLETE SPECIFICATION
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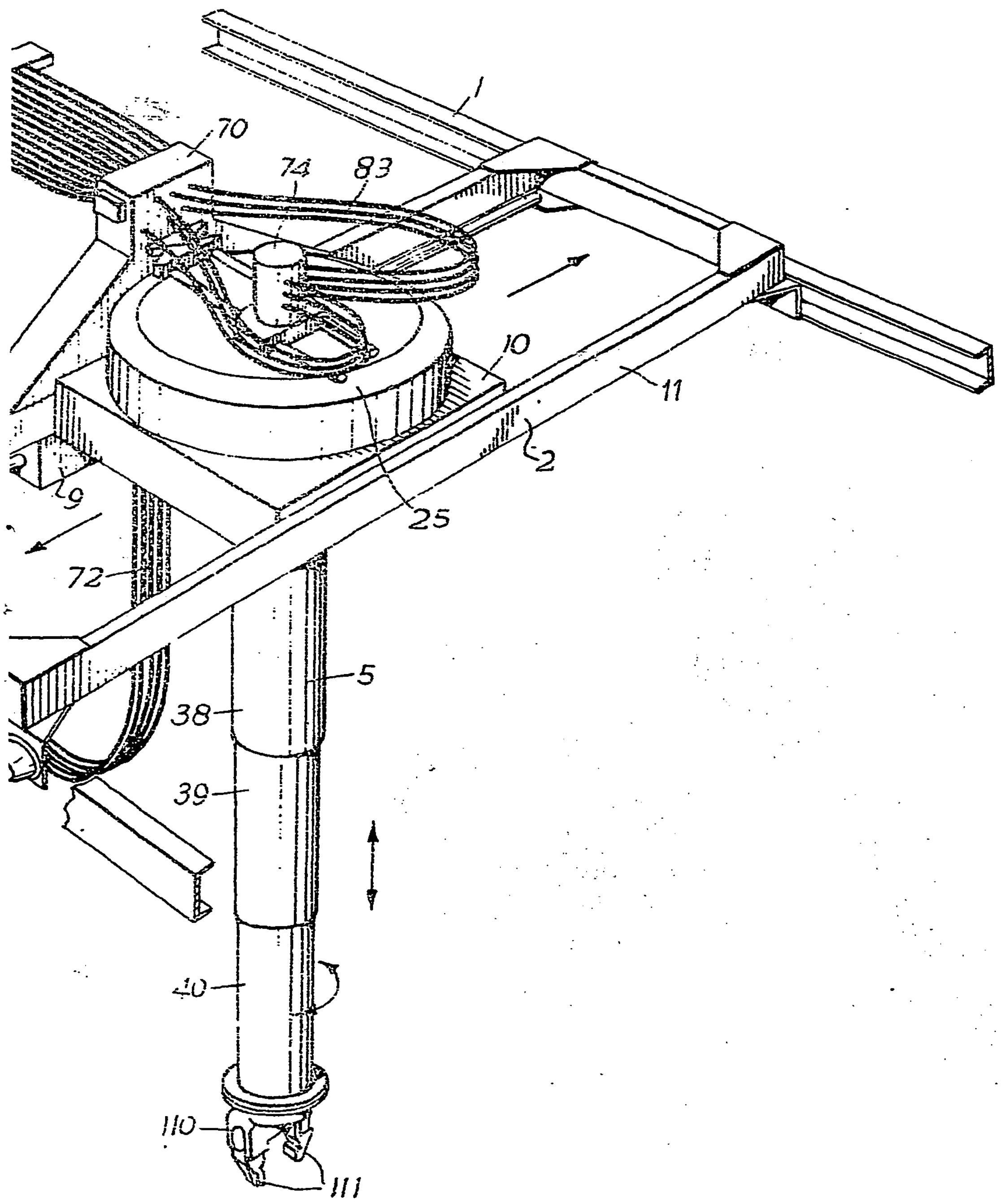

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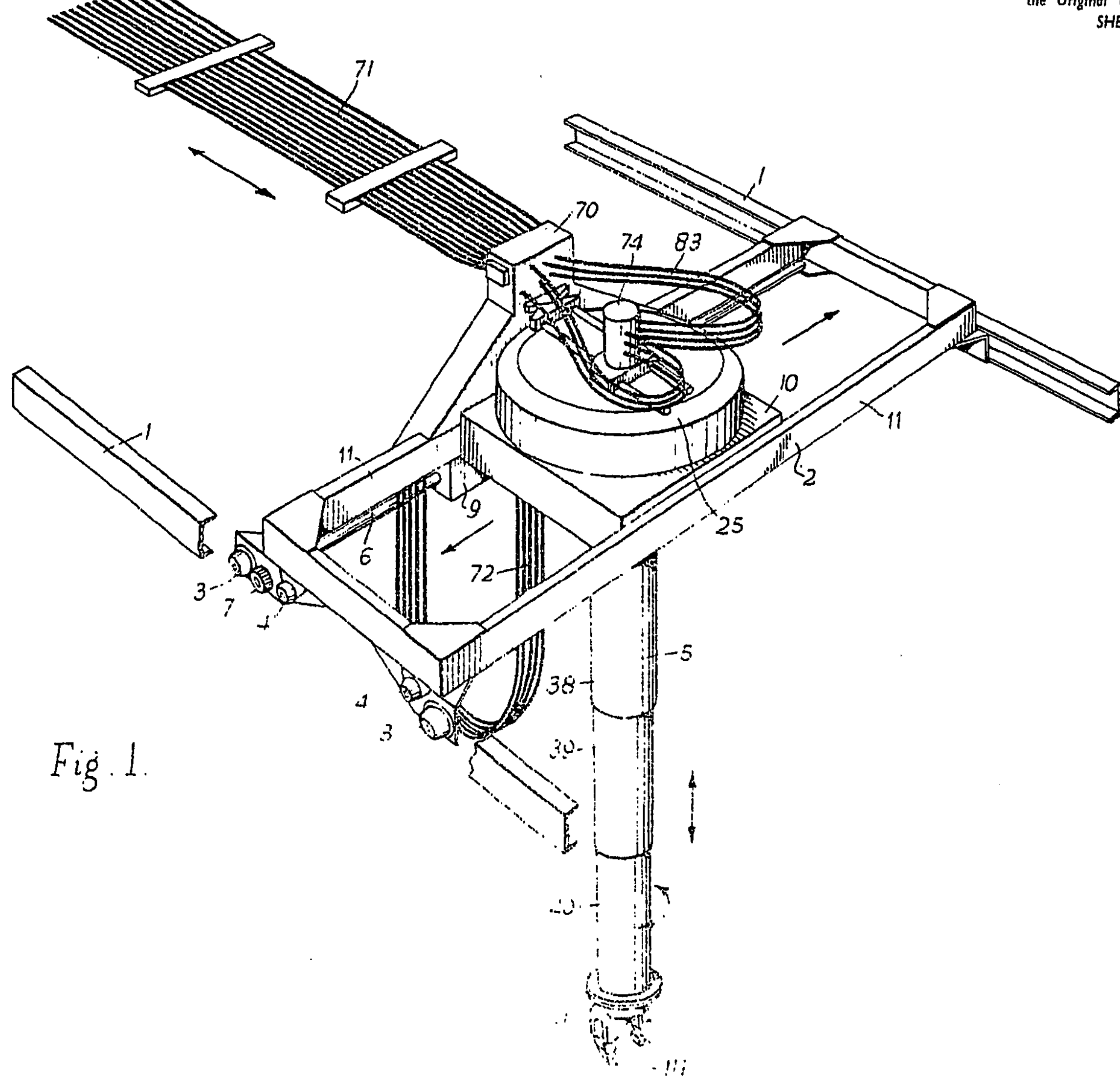
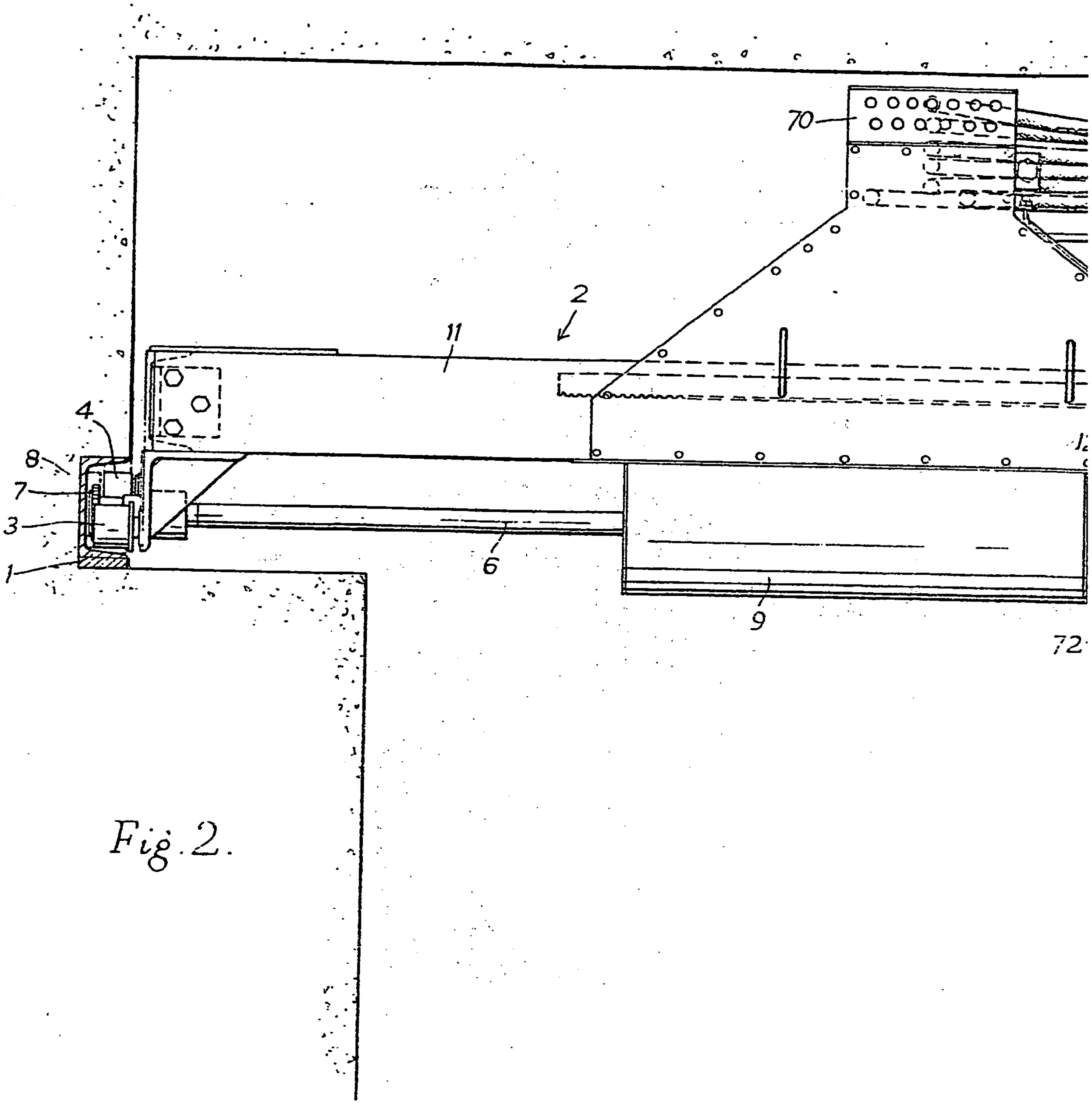


Fig. 1.



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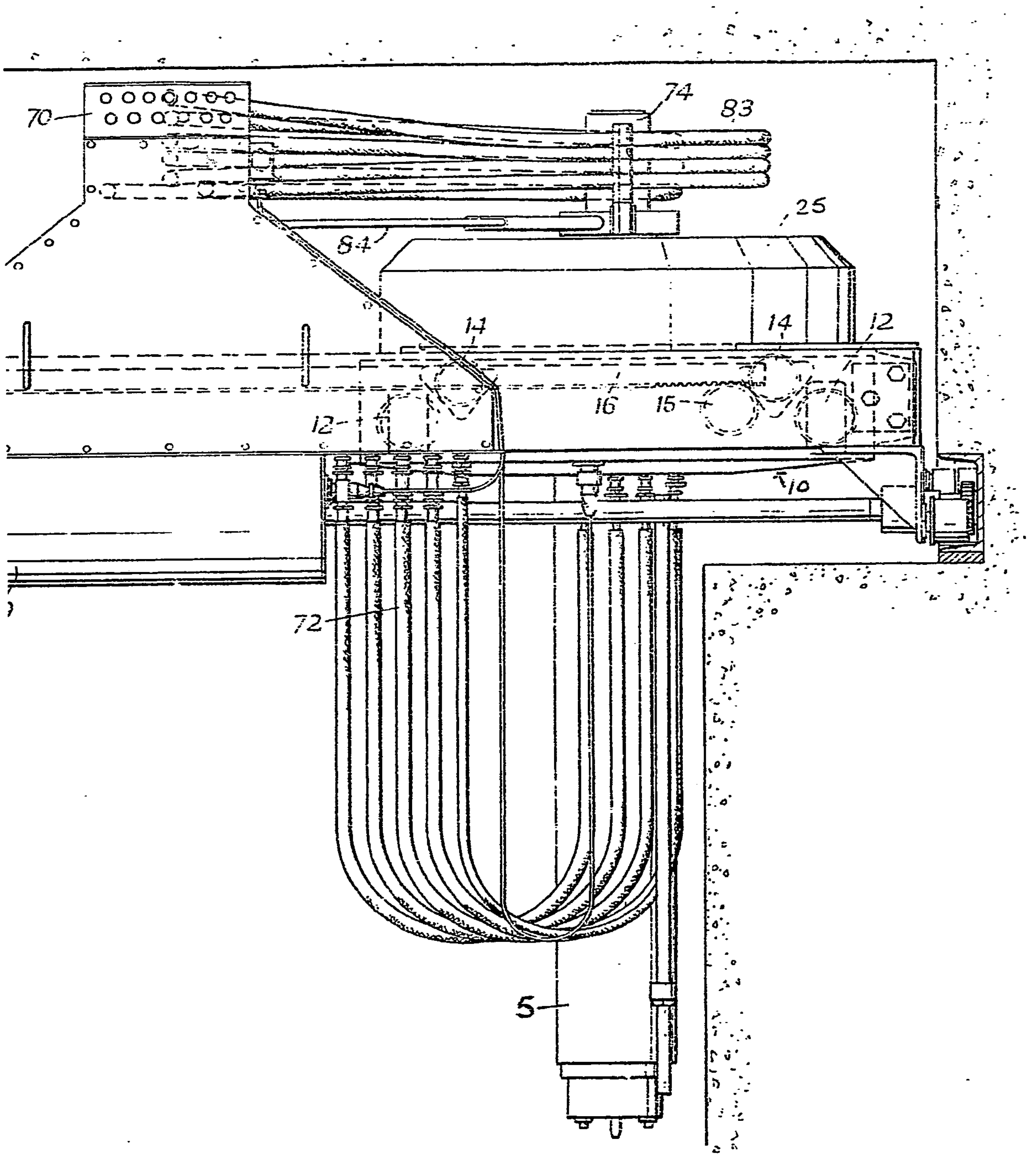
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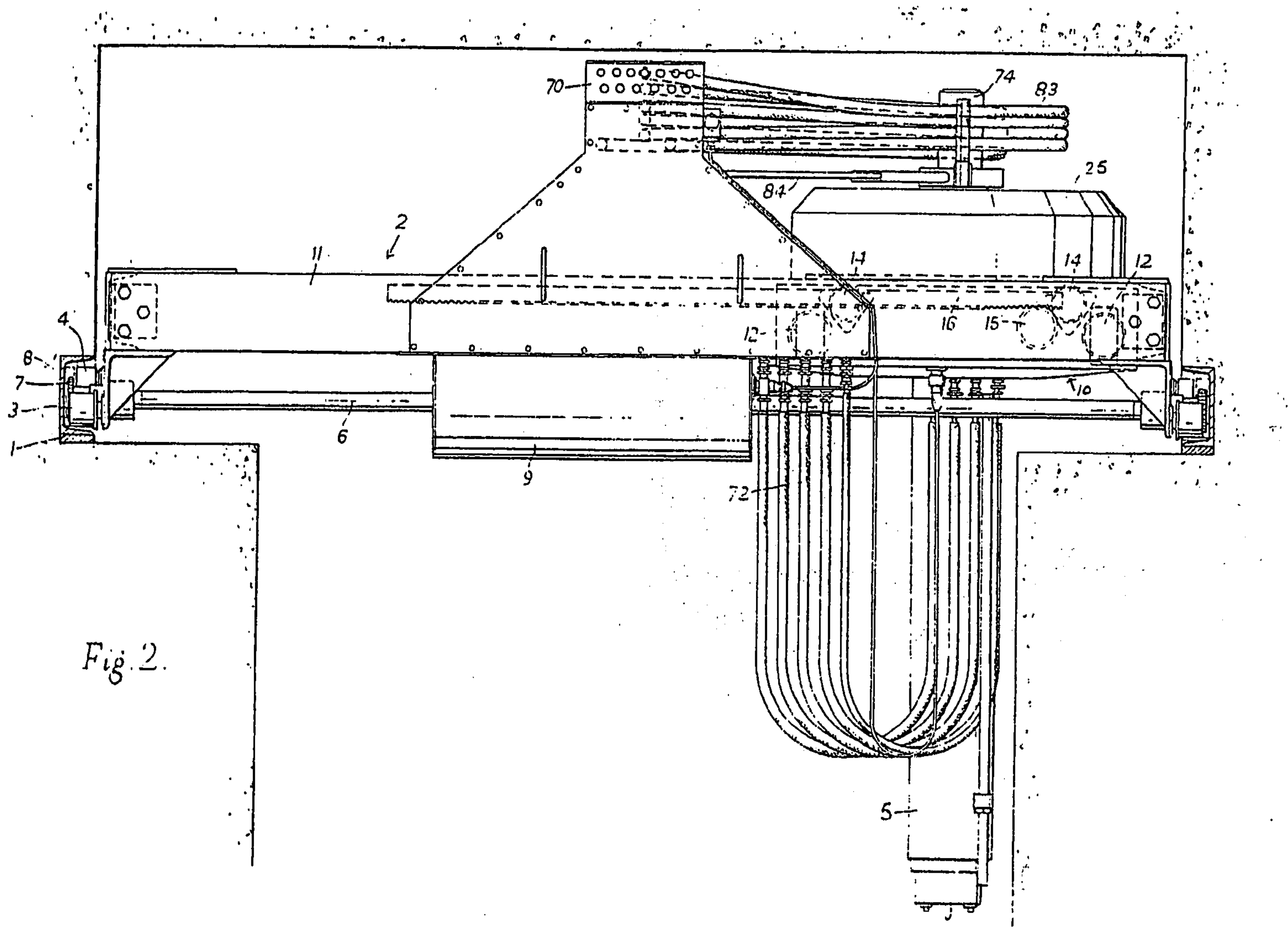
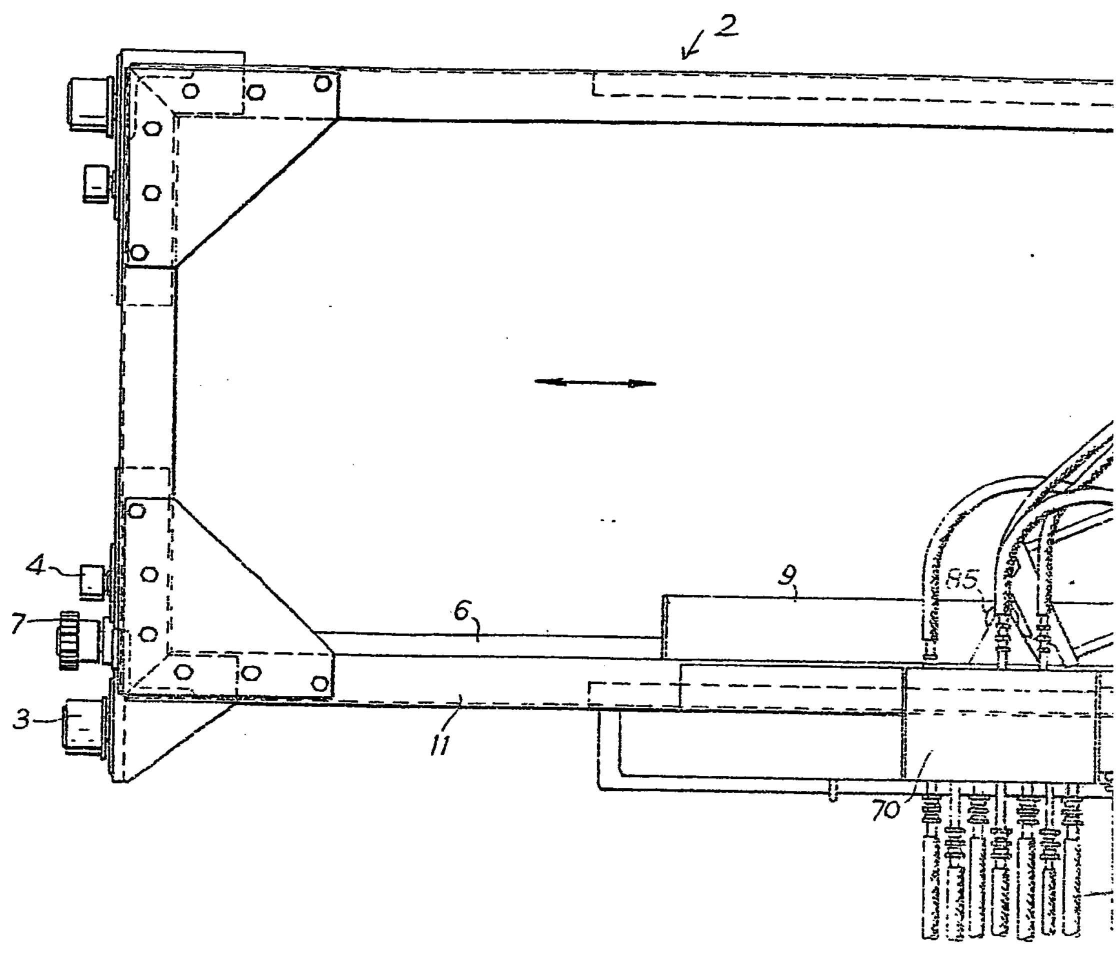


Fig. 2.

Fig. 3.



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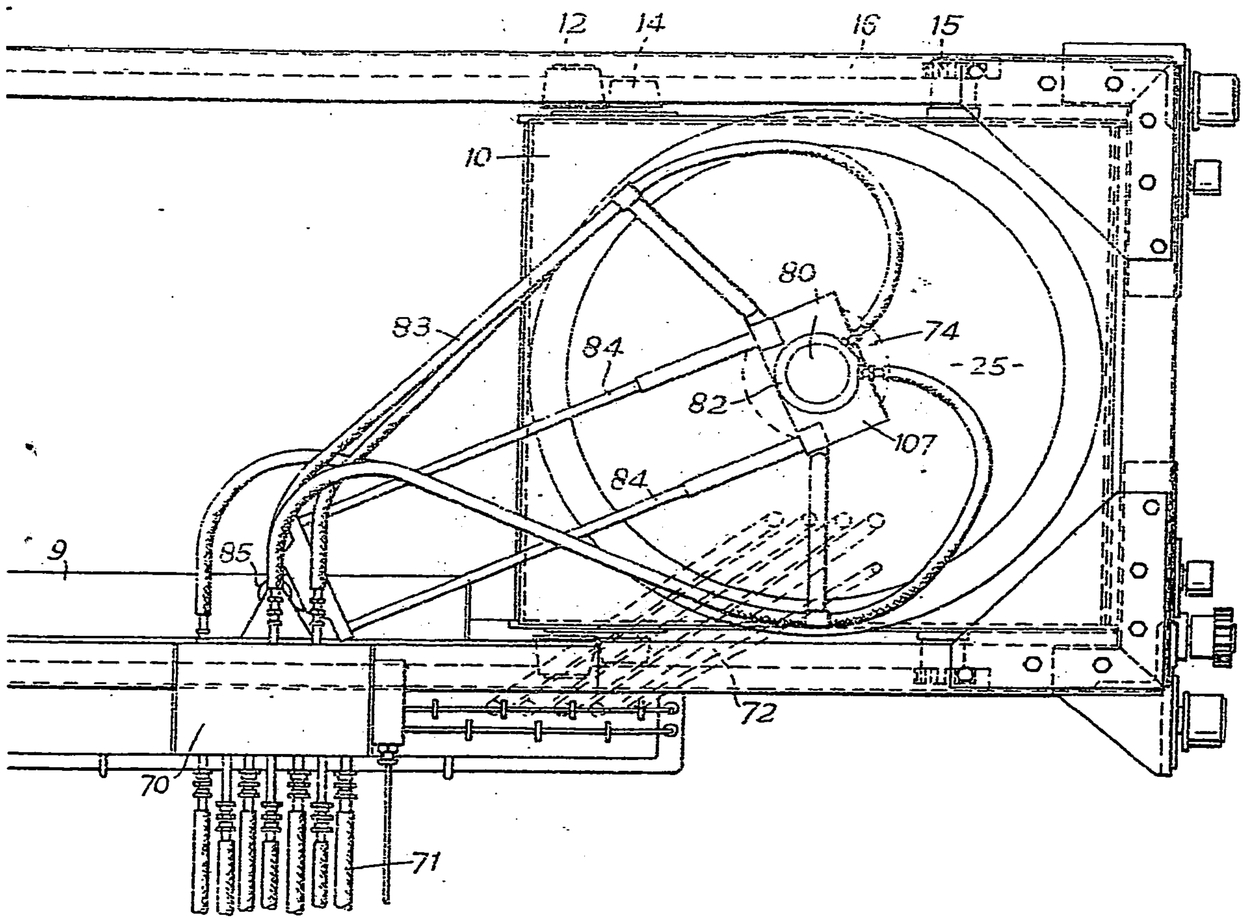
SHEET 3

Fig. 3.



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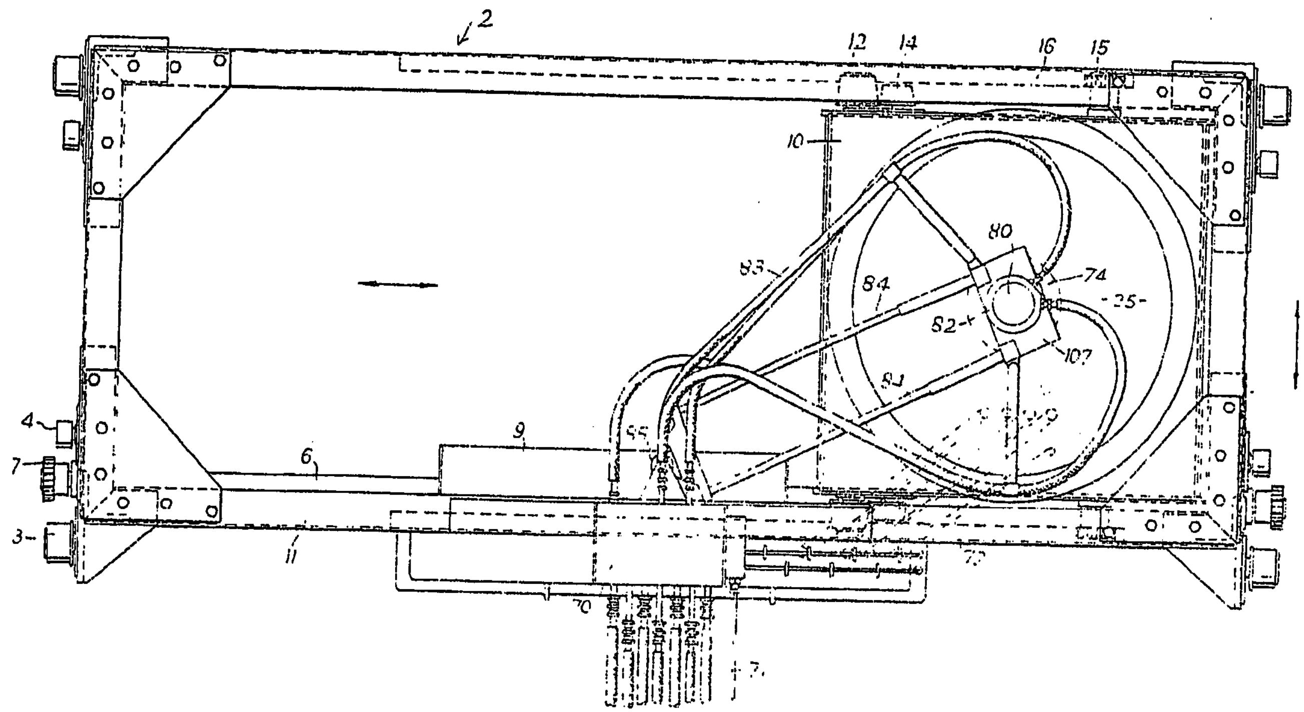
SHEET 3

Fig. 3.



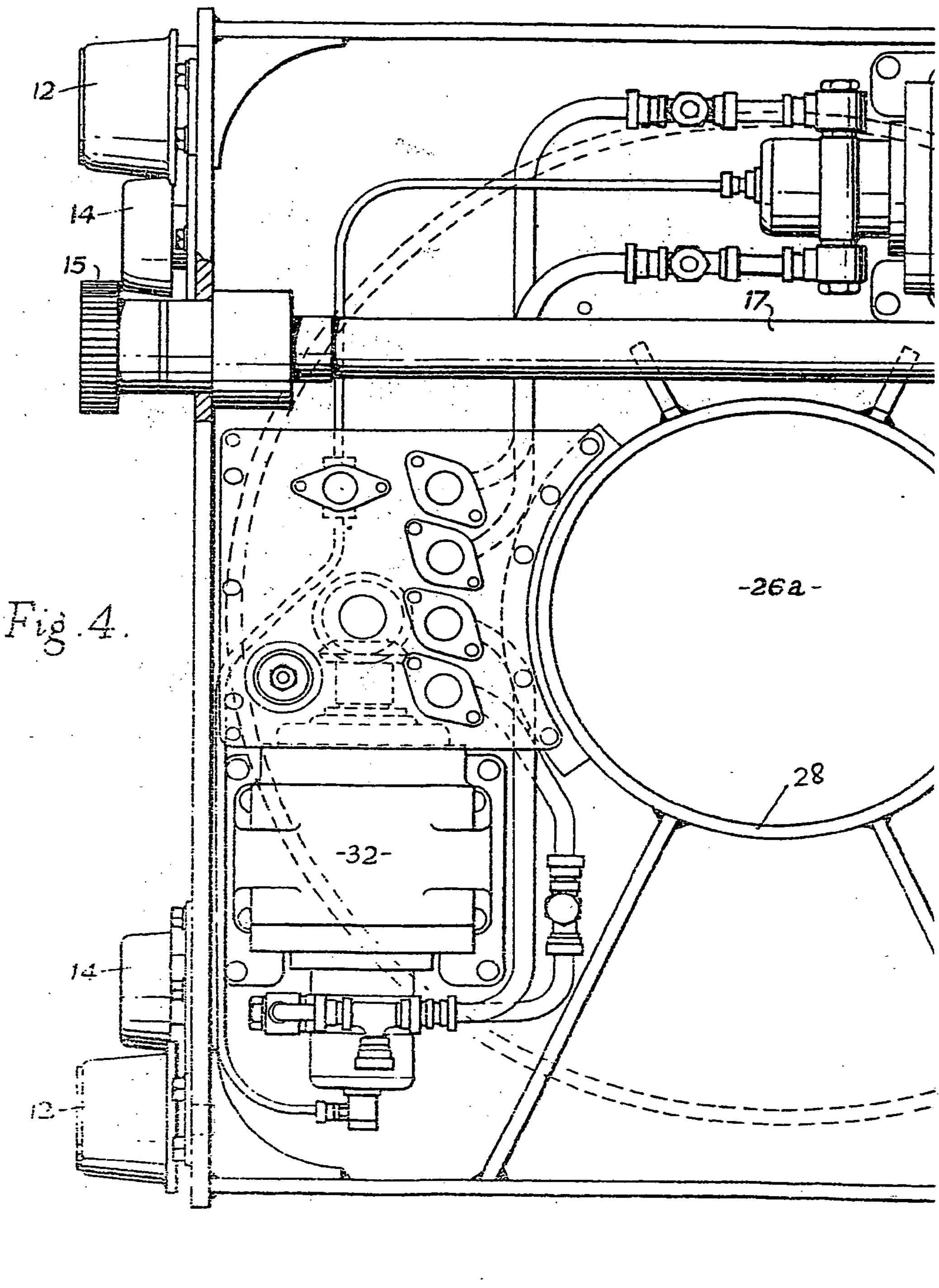


Fig. 4.

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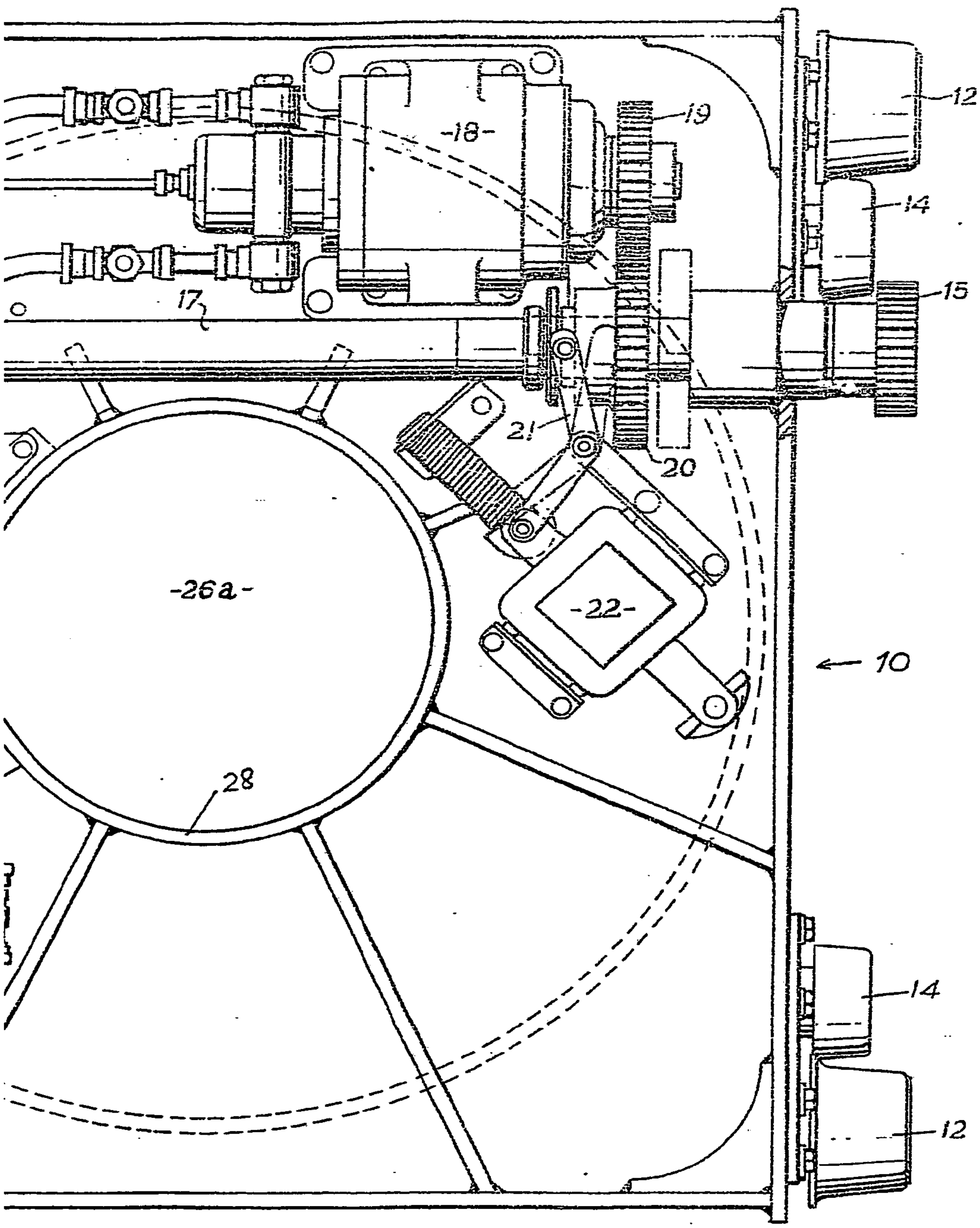


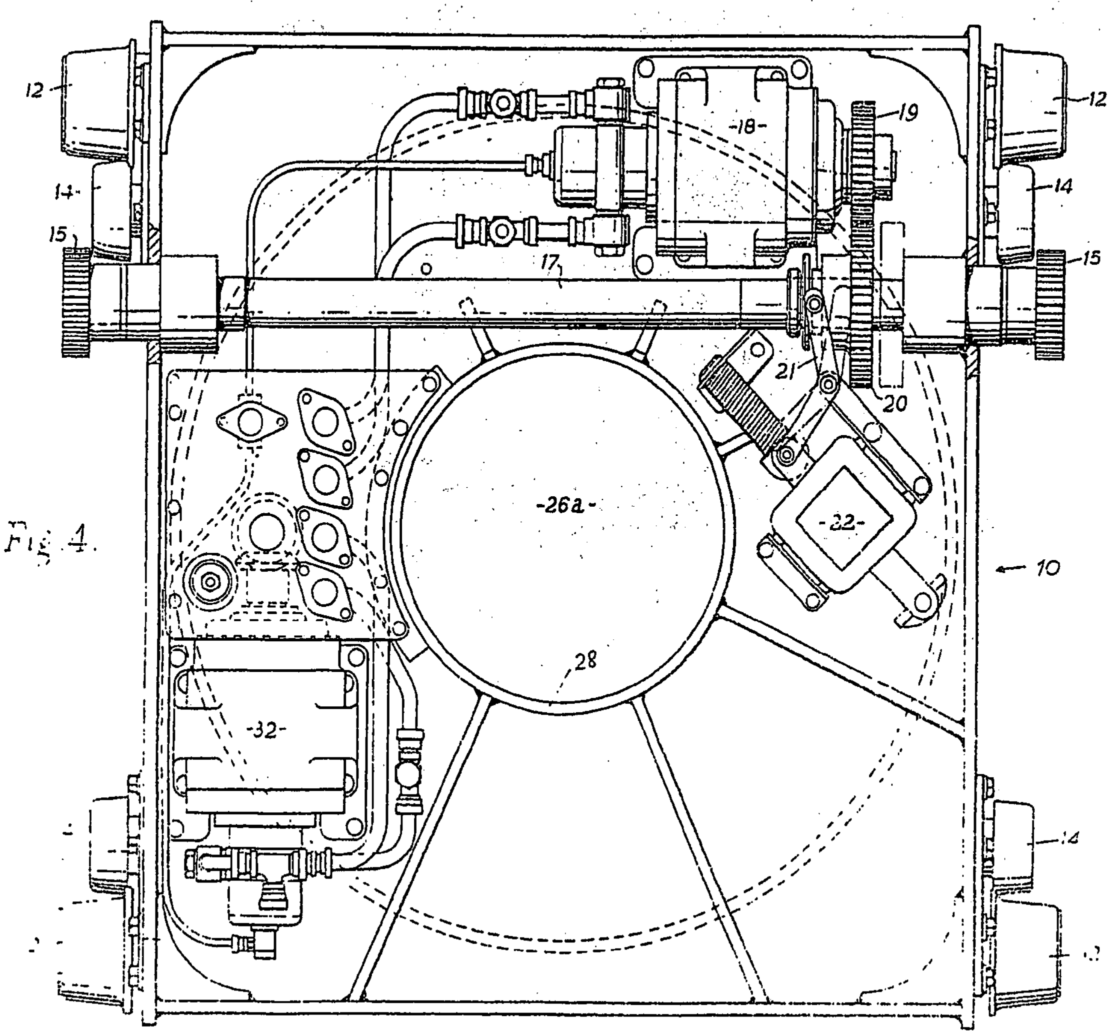
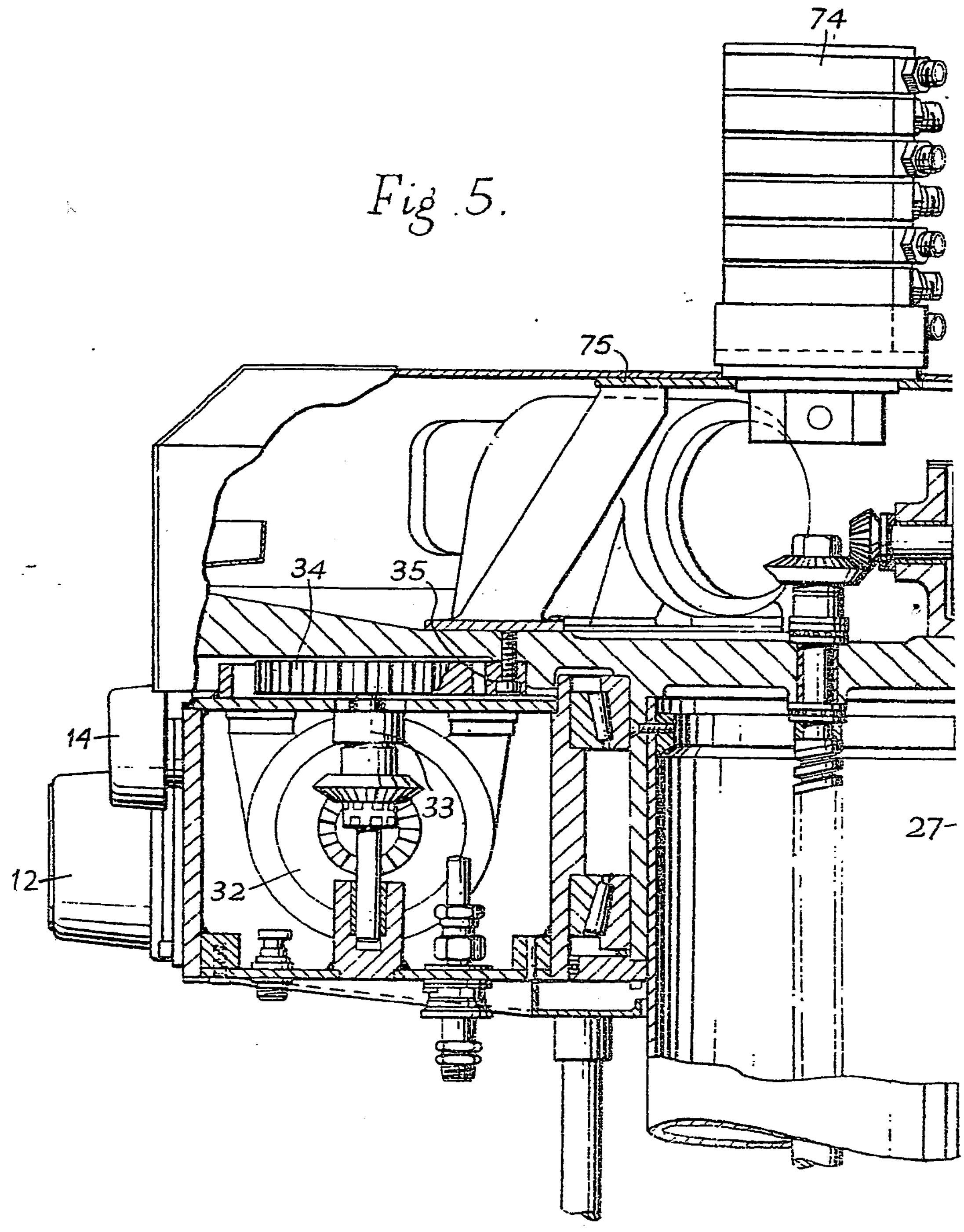


Fig. 4.

Fig. 5.



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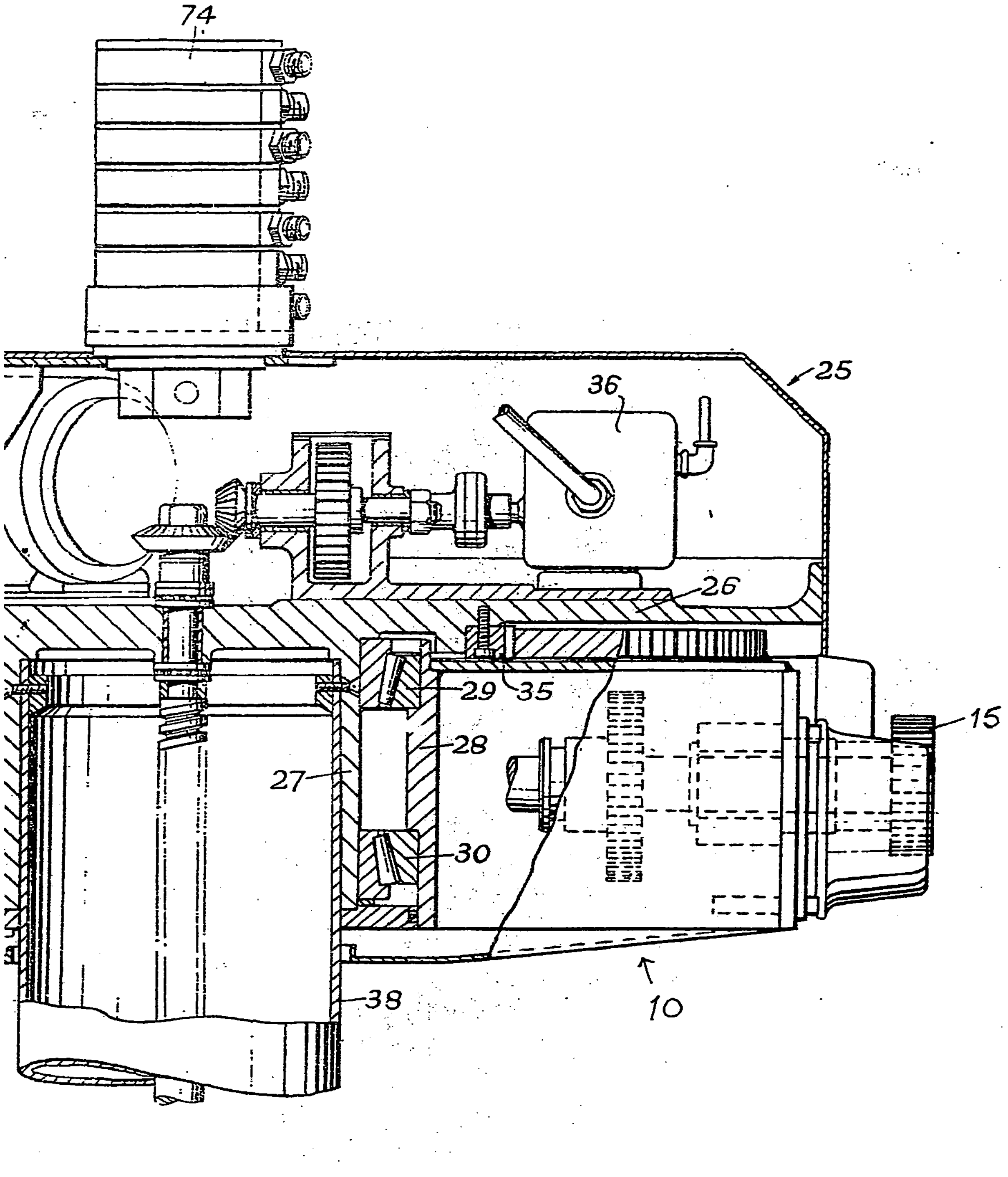
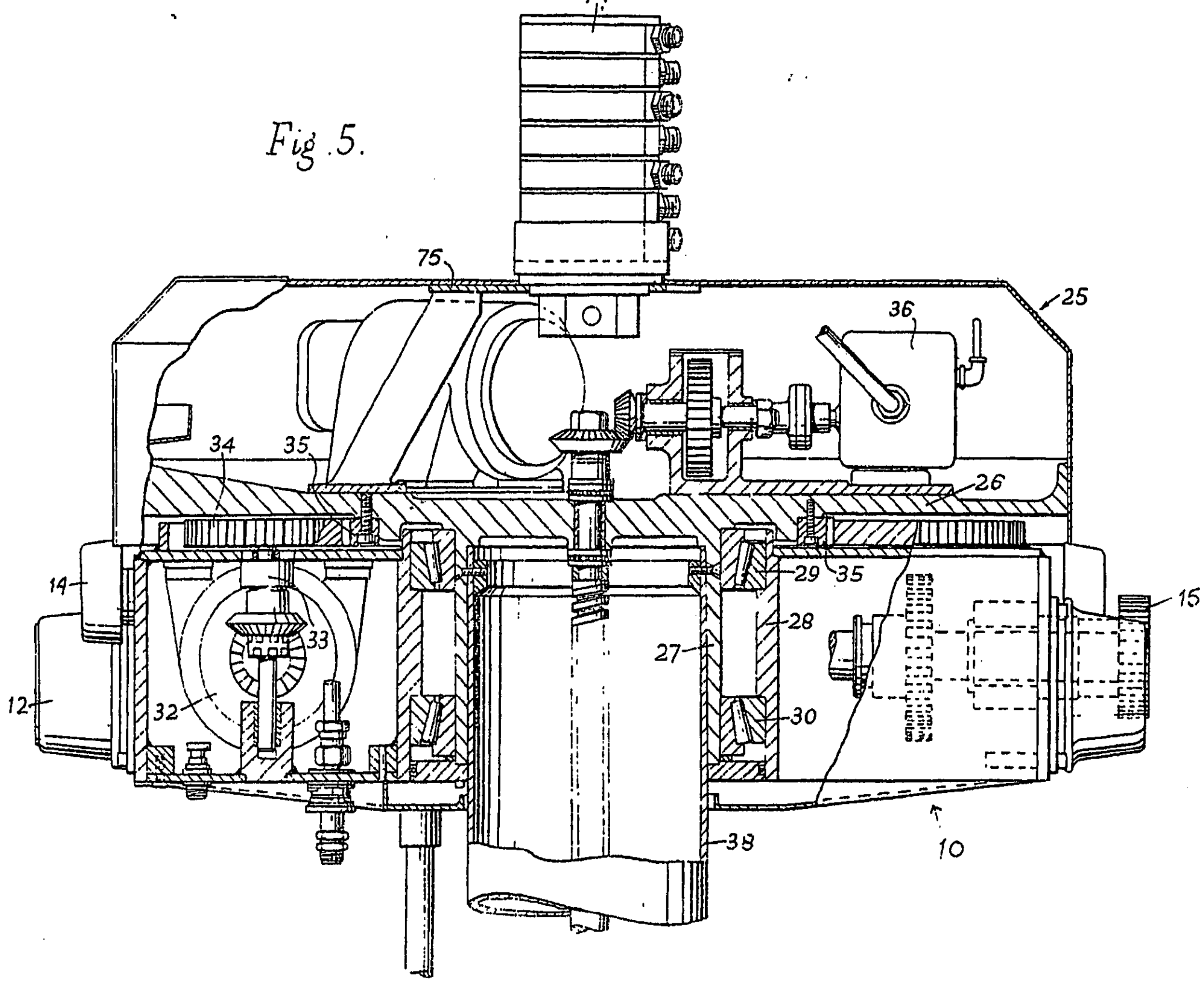


Fig. 5.



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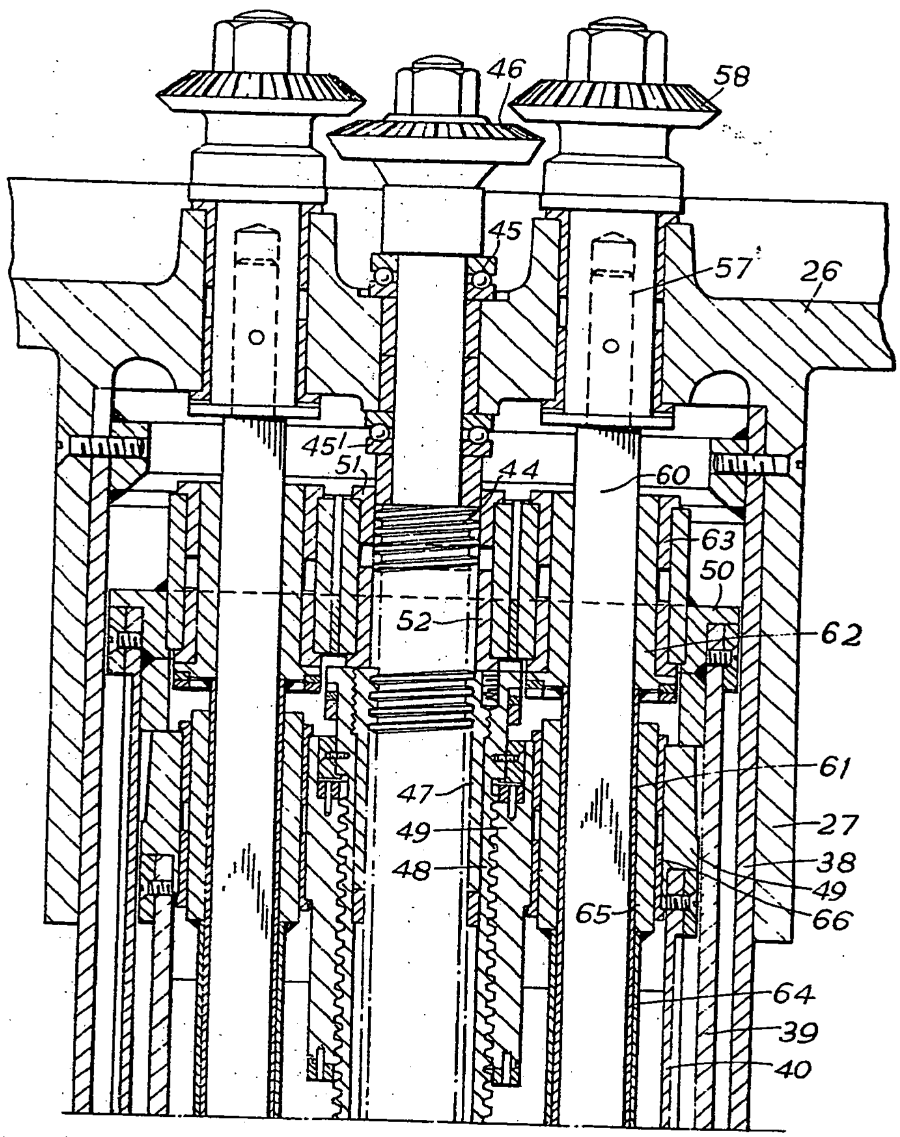
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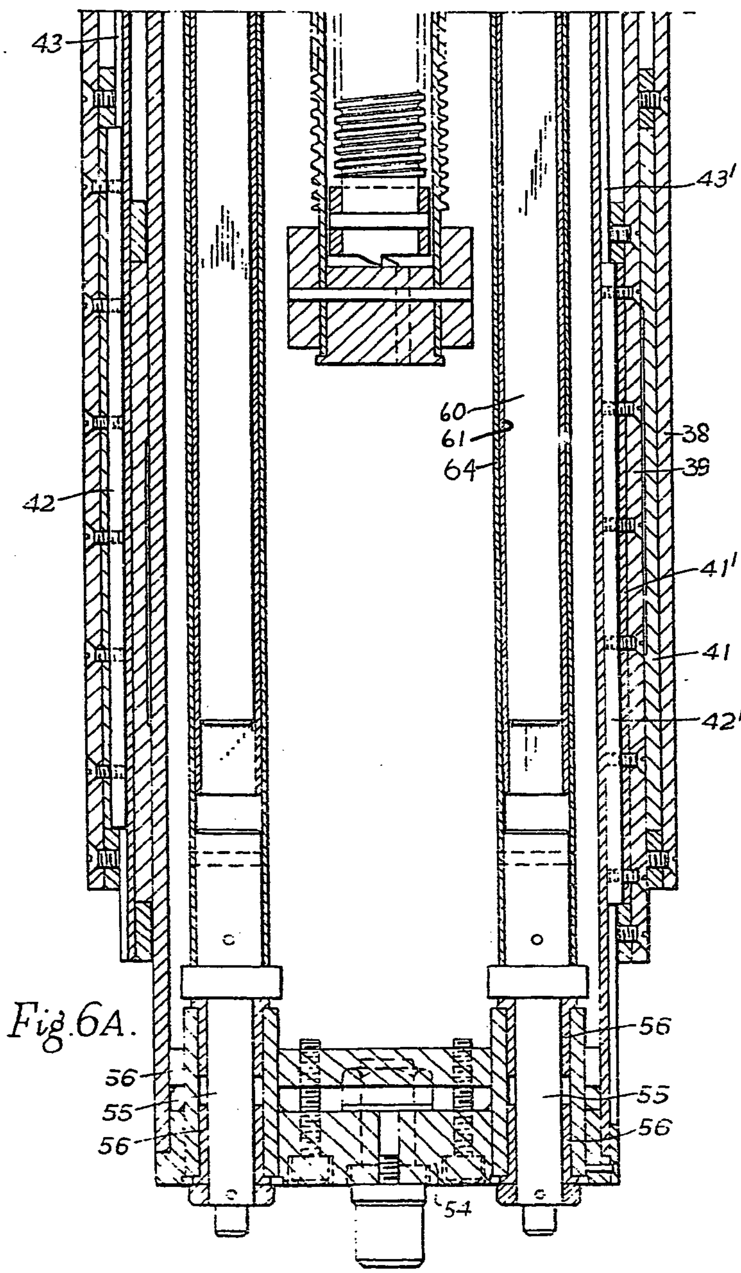

Fig. 6A.

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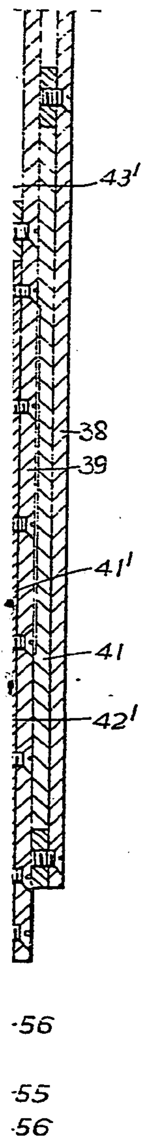
SHEETS 7 & 8



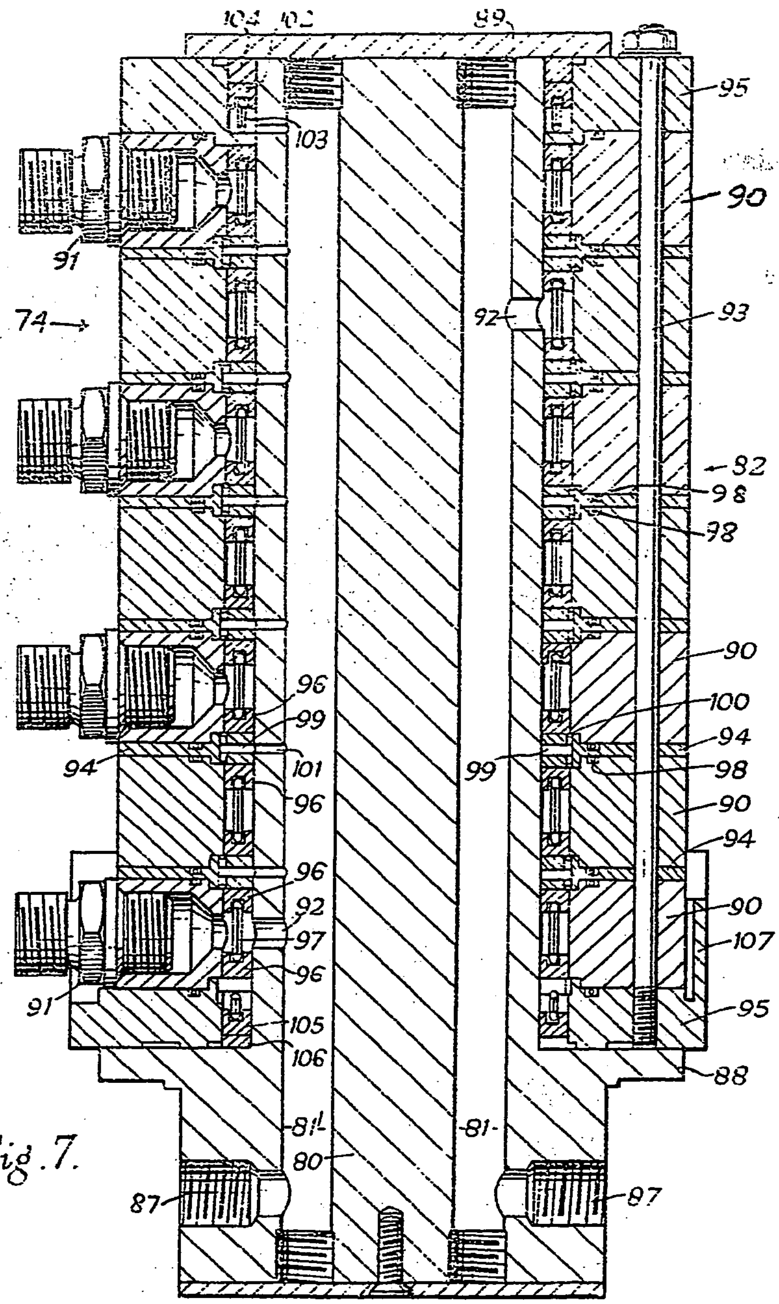


Fig. 7.

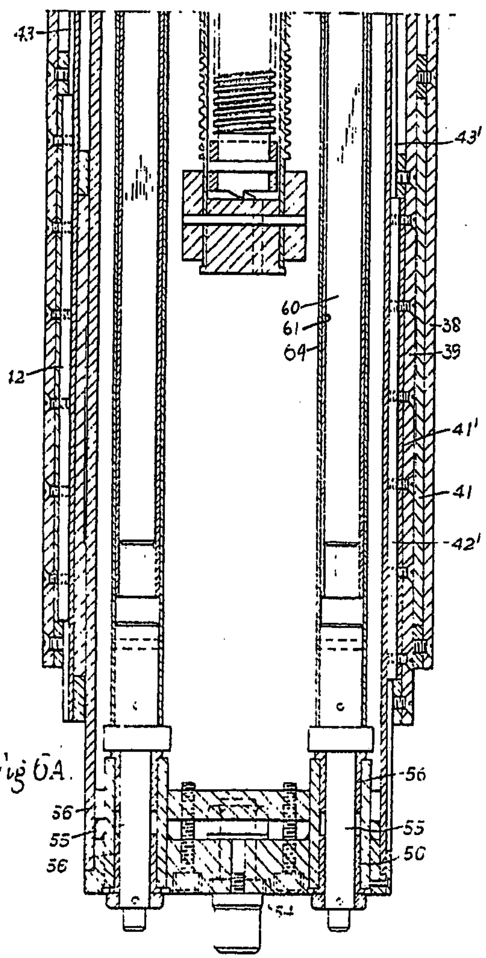

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Fig 6A.

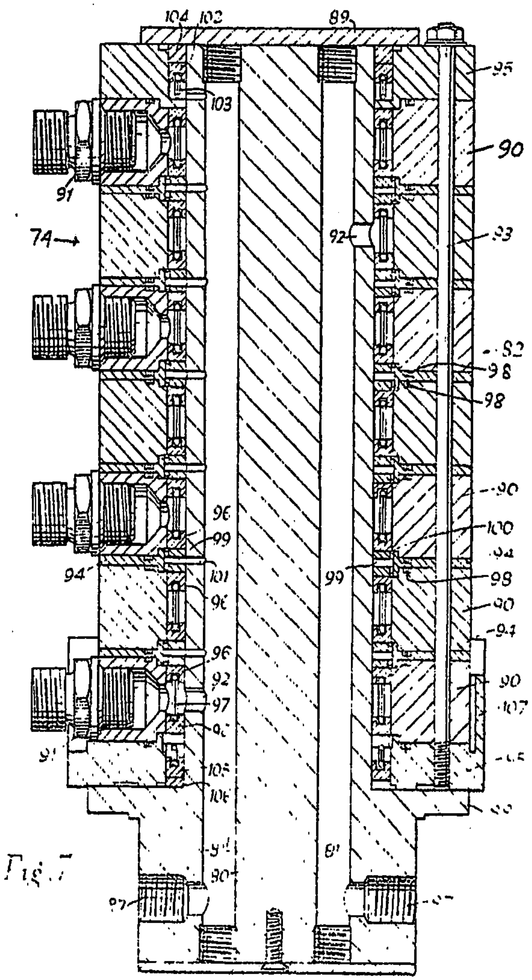
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Fig. 7